Study of the mechanical impact of distributing the core curriculum of an engineering faculty in the two first years

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ABSTRACT

Retention is a main issue in engineering curriculums. Many experiences have been done to increase retention, including First year experience or the distribution of courses from core curriculum during all sessions of the program. When courses from core curriculum are distributed in 2 years, it is difficult to evaluate the real impact of such modification. A simulation of this transformation shows that without any other modification, this distribution mechanically increases the students retention, decreases the grade performance average, decreases the failure rate and increases the rate of students leaving after 3 fails in the same course. Those results compared with the observed one are important to evaluate the real influence of the transformation on students retention and students motivation.

1 Introduction

Attrition in university and particularly in engineering school is an important issue. A lot of efforts are deployed to select and educate student that finally leave the school, either because they don't reach academic expectation, or because they simply change their curriculum choices.

The determinant of success of a student arriving at university has been largely studied (M. Besterfield-Sacre and al. 1997, Burtner 2005). Clearly, retention depends upon many factors. Predictive factors have been searched in many directions, for example:

- the previous academic results and cognitive abilities
- the environment parameters (distances, ethnicity, finance, working during studies)
- emotional intelligence (Parker et al. 2006)

Even if more parameters are always pertinent, it is clear that the most powerfull predictor is the High School GPA (Murtaugh, Burns, & Schuster, 1999), even better that the SAT scores. Models have been proposed to predict retention (Burtner 2005).

In most engineering faculties (or school) the first year is dedicated to a core curriculum. This core curriculum aims to prepare the student with basic scientific and mathematic knowledge, to have an economy of scale by gathering students of all engineering curriculums in the same classes, and obviously to identify as early as possible students which are not able to reach the expected academic level. Usually, this first year induces courses with higher failure rates and lower grade point average. A side effect of this first year can be a demotivation of students which expect engineering experience from the beginning of their studies. To avoid this unexpected attrition, there are two well documented approaches:

- first year experience (many publications during the last 10 years)
- distribution of core curriculum courses in 2 years by introducing engineering courses as of the first year

The first year experience is well documented and the first year experiences began in the 1950's in Australia (C. McInnis 2001, K.-L. Krause and al. 2005). Research focuses in social integration, pedagogical methods, size of group and other factors that have been identified as determinant for student attrition (Betsy 2000, Tinto 1999). The second approach is less documented.

The research question addressed here is: how a change of organisation can mechanically change the perception of students performances in an engineering school (in term of failure rate and Global Performance Average).

This paper studies the second approach. After implementing this transformation of the curriculum in an engineering school, we have observed a lot of changes in academic results and in professors's perceptions. It was difficult to attribute those changes or those perceptions to curriculum modifications or to some exogenous parameters. So we decided to evaluate the mechanical effect of curriculum modifications (all other parameters being equal) on academic parameters.

2 Research method

The research question is to understand the technical impact of the suppression of the first year in an engineer school, in order to anticipate potential problems. The research studies the transition between the two following situations:

- <u>Situation 1</u> : the curriculum includes a first year with most of theoretical courses (mathematics and general science, physics, chemical, etc.), with a reputation of selective courses (higher level of failure and smallest performances). Then students enter the engineer programs, courses have a smaller failure rate and usually best average evaluations.
- <u>Situation 2</u> : students enter the program as of the first years. Theoretical courses are distributed among the 2 first years, and engineering courses began from the first semester. So the 2 first years present a mix of classical "core curriculum courses" and more applied courses.

The research uses a model of a population of students, and a simulation of the behaviour of this population in situation 1 and situation 2, and compare results.

We have used a simulation software to simulate 20 semesters of an engineering school with 1000 new Students per year with a core curriculum in first year. Faculty has 3 academic expectations: a threshold for global grade point average, a threshold for minimum semester grade average and a maximum of 3 attempts (fails) for the same course. We study failure rate and failure causes, averages and failure rates in different courses and the global attrition level. Core curriculum courses have higher failing rates and lower grade averages than other courses.

The research method can be described by the following steps:

- Define a model of students and of the determinant of success
- Define a model courses, notations, academic rules
- Define the parameters to be observed
- Simulate situation 1 and calibrate parameters with historical data
- Simulate situation 2 and compare both situations
- Validate the model with observed phenomena

The simulation uses an industrial software for discreet events simulation: ARENA. This tool is broadly used to simulate industrial problems.

2.1 Simulation model.

The simulation model describes the behaviour of the observed engineering school:

- A normal curriculum with 90 credits split in 6 sessions of 15 credits each,
- The curriculum includes 30 courses, 3 credits each
- For each course, initial scores are on a scale of 100, but final marks are (A, B+, B, C+, C, D+, D, F). The instructor defined the minimum value for D and the value for A; the remained interval is uniformly split for other marks.
- The global mean of the student is computed by transforming marks in value (4, 3.5; 3; 2.5; 2; 1.5; 1; 0)
- A student is not allowed to pursuit if one of the following occurs
    - A session with a session mean under 1.2
    - 2 consecutive sessions with a mean under 1.75
    - 3 fails on the same course (named 3F)
- If a student fail a course, he must take it again in the following session
- If a course has been failed, and succeeded later, the best mark is kept

Even if the observed school is a 4 years curriculum, the choice to limit to 3 years had been done for technical reasons, and the last year is not really concerned by the study.

2.2 General Performance Average modelling

The model assumes that the students receive for each course a mark according to a "global performance Indicator" GPI that is used at a predictor for student scores obtained in each course.

The GPI is computed as a random variable, distributed as a triangular variable,

GPI = TRI (Min, Probable, Best)

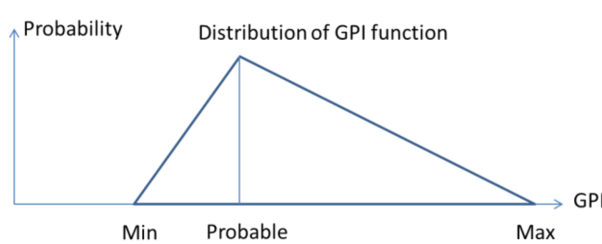

Figure 1 : model for the GPI of incoming students

This triangular distribution has been chosen to match with Quebecois system: students enter a university according to their GPA (named cote R in Quebec) and each university announce a minimum value. The distribution of this "cote R" is well modelled by a triangular.

For a given student, every score (in a course) are computed using a normal distribution, centered on its GPI with a given standard deviation (The model is: Mark = Normal (GPI, Standard deviation)):

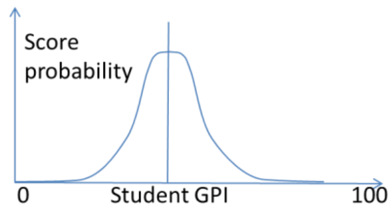

Figure 2 : model used to compute a score with a given GPI

The relation between the score (1-100) and the marks (A, B+, B…) is obtained by 2 bounds and equally distributed intervals, as shown in .

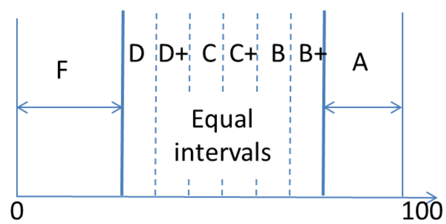

Figure 3 : model to obtain a mark from a score

So the transformation is perfectly defined by only 2 values [V1; V2], the limit for the D and for the A. The first limit V1 characterize the "minimum standing" required by the professor. The second induces the average score obtained by the group.

3 Results

For confidential reasons, real values are substituted as soon as they can be considered as strategic for the institution. The results have been obtained with a simulation of 10000 students arriving in the institution during 20 different sessions. All students can be considered as independent variables (in the model) so this led to sufficient confidence intervals.

3.1 Calibration

In the first step, the situation 1 is modelled in order to calibrate the course model to the real situation. The situation observed in the engineering school shows a strict increasing average. Most failures occur during the 2 first sessions, and the average during the first year was largely smaller than the subsequent session. After the first year, the average continued to grow, but much more slightly.

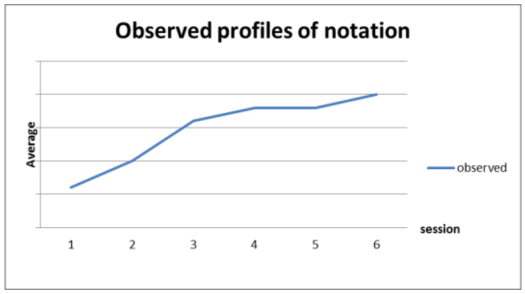

Figure 4: observed evolution of the global students' average during sessions of the program

We have tested 2 Assumptions:

Assumptions 1: All courses have the same difficulty and the difference of results is only related to the fact that students with most difficulties fail during the first year and consequently the population in remaining courses is stronger.

Assumptions 2: courses of the first year are more difficult and the notation is different: the threshold of success is higher in first year than in subsequent courses.

To test both assumptions, the simulation has been used with all courses sharing the same [V1; V2] values defined Figure 3. Some results are given

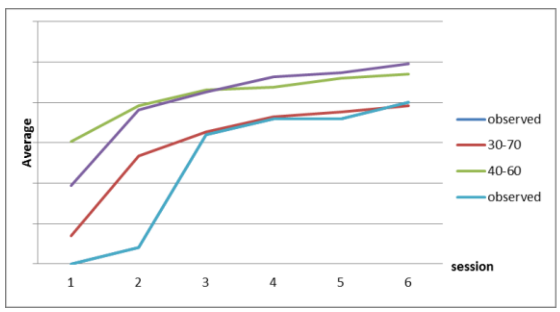

Figure 5: diffrent shape of notation

Clearly, it is difficult to obtain the good shape for session 1 and 2. But the most problematic point is that the best fit (obtained with 30-70) leads to a failure rate 3 times higher than the observed one.

By using 2 types of courses, with 2 sets of values, it has been very easy to model observations.

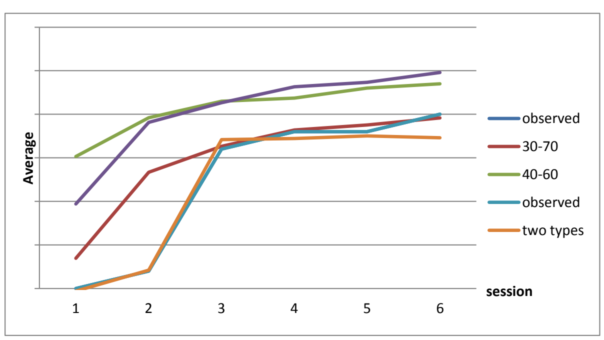

Figure 6: Global Performance with two types of course

In this simulation model, the distribution has been limited to 2 courses:

- Difficult courses, type A (A1, A2)
- Normal courses, type B (B1,B2)
- with B1< A1< B2< A2

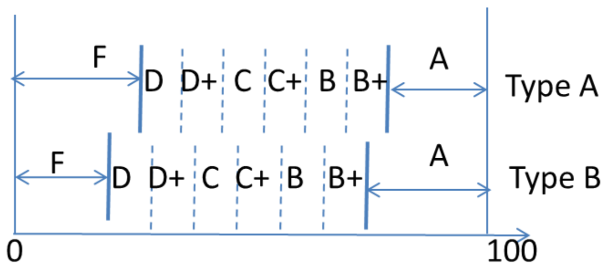

Figure 7: two courses characteristics

3.2 General attrition

Globally, the first results are the followings:

- The total number of failing courses increase of about 8%,
- The retention rate increases about 10%.
- The general mean in courses decrease of 7%.
- The number of 3F doubles.
- The mean in the first courses of class 1 increase
- The mean of all other courses of class 1 decreases of about 5%
- The mean in first courses of class 2 decreases of 15%
- The mean of other courses of class 2 decrease, but less than 2%

Concerning the attrition, it is surprising to see that the number of student leaving for “poor standing” decreases. In all simulation, the retention increase from about 10%. Simulation shows that the global average of students during the first year increases (due to the fact that there are some easier courses from the beginning). This is not compensated by the difficulties of courses during the second year. In the same time, the total number of failures (in courses) increases in situation 2. Less students leave, so some “low standing” students stay longer or even pass the program and consequently fail more courses.

The consequence of this retention increase is the decrease of the General average of the program. While more students pass the program, the one that pass in situation 2 and would have failed in situation 1 has clearly a weaker standing than the average.

The most surprising result is that the number of 3F (students that leave with a correct standing, with 3 consecutive failures at the same course). Typically, among the student that leave, the ratio of students that leave for 3F increases from an interval of [10%-14%] to an interval of [25% - 33%]. This is a major change. The Figure 7 is a typical result of one of the simulation: not only we have not far from twice more 3F in situation 2, but the 3F occur with much more credits already obtained, and a good global average.

This situation was not anticipated and the consequence is that a large number of students seems to be expelled after a long period in the program, without any diploma.

Finally, the last results are the difference of behaviour between courses for the average. Concerning the courses that are in first year in situation 1 (difficult courses) the first ones (first session) seem to have an increasing average (small increase), and the other ones have a small decrease of their average. The courses that used to be in the second year (in situation 1) and that have been moved in first year (in situation 2) have a strong decrease of their average; the other one had a small decrease.

Nb students		number of credit when leaving				
mean	15-29	30-44	45-59	60-74	75-90	Total
1-1,2	1					1
1,2-1,4	1					1
1,4-1,6	2					2
1,6-1,8	9	5				14
1,8-2	11	12	5	1		29
2-2,2	10	6	1	1	1	19
2,2-2,4	3	9	2			14
2,4-2,6	2	1	2	1		6
2,6-2,8		1		1		2
2,8-3		2				2
3-3,2		1				1
Total généra	39	37	10	4	1	91

Situation 1

Nb students		number of credit when leaving				
mean	15-29	30-44	45-59	60-74	75-90	Total
1-1,2	1					1
1,2-1,4	4					4
1,4-1,6	6	5	2			13
1,6-1,8	4	3	4	2		13
1,8-2	9	8	10	4	1	32
2-2,2	5	16	12	9	2	44
2,2-2,4	4	6	6	8	1	25
2,4-2,6		1	4	4		9
2,6-2,8	1	1	1	2		5
3,2-3,4		1				1
Total généra	34	41	39	29	4	147

Situation 2

Figure 8: position of the 3F in the curriculum

The results on the average are not surprising.

4 Discussion

By observing the situation 2 in the real system, we have observed an increasing rate of retention, a small decrease of general average, a decrease of average in the courses of the first year in situation one, and of the courses that have migrated from second to first year. We have also observed problems with an increasing number of 3F that nobody has connected with the new situation.

By comparing both, it appears that the improvement of students retention is largely due to a mechanical effect. Only a small part of this amelioration is due to the retention of “high standing” students which previously left school because they wanted engineering courses earlier. Simultaneously, we have been reassured to see that the decrease of mean was not related to a degradation of students’ efforts.

The only observed phenomenon that cannot (until now) be explained clearly is the decrease of the mean in first year courses. This still has to be investigated. Actual hypothesis is that students in first year give more efforts for the courses that moved from second to first year because they are the courses for which they have chosen the program.

Finally, the simulation has explained the increase of 3F for which many people had already found an other exogenous explanation.

5 Conclusion

When a major change is decided in a curriculum, it creates hopes for some and of the anguishes and the fears for the others. The firsts are sure to improve motivation, learning and behaviour of the students. The seconds believe that "low standing" students will profit from the system and that the level will decrease. This is a natural behaviour. When comes time for the assessment, the good points confirm the firsts in their hopes and problems confirm the others in their anguishes.

But in many cases, observed results are not a consequence of an evolution of the behaviour, but just a mechanical effect of decisions.

Simulation of even a small model can put the stress on mechanical transformations induced by organisational evolutions. Then, the observed parameters should be compared not only to the initial situation, but also to the simulated results. This permits to determine the real benefits of the change.

References

Barefoot B. O., The first Year experience, Are we Making it Any Better ?, About Campus 2000*, 4*(6), pp. 12-18..

Bestesterfield-Sacre M., Ataman C. J., Shuman L. J., Characteristics of Freshman Engineering Students: Models for Determining Student Attrition in Engineering, Journal of Engineering Education, April 1997, pp 139-149

J. BURTNER , The Use of Discriminant Analysis to Investigate the Influence of Non-Cognitive Factors on Engineering School Persistence, Journal of Engineering Education, Jully 2005,pp 335-338

Knight D. W., Carlson L. E., Sullivan J. F., Improving Engineering Student Retention through Hands-On, Team Based, First-Year Design Projects, 31st International Conference on Research in Engineering Education, 2007, Honnolulu, ISBN: 0-87823-193-5, pp 1-13

Krause K.-L., Hartley R., James R. and McInnis C., The First Year Experience In Australian Universities : Finding from a decade of National Studies, Final report 2005, ISBN: 0 642 77531 1, 115 pp.

Mcinnis C., Researching the First Year Experience: where to from here?, Higher Education Research & Development, Vol. 20, No. 2, 2001

Murtaugh, P. A., Burns, L. D., & Schuster, J. (1999). Predicting the retention of university students. Research in Higher, Education, 40, 355–371.

Parker James D.A., Hogan Marjorie J., Eastabrook Jennifer M., Oke Amber, Wood Laura M., Emotional intelligence and student retention: Predicting the successful transition from high school to university, Personality and Individual Differences 41 (2006) 1329–1336

Parker James D.A., Austin Elizabeth J., Hogan Marjorie J., Wood Laura M., Bond Barbara J., Alexithymia and academic success: examining the transition from high school to university, Personality and Individual Differences 38 (2005) 1257–1267

The Stationery Office, Staying the course: The retention of students in higher education, Report by the comptroller and auditor general, HC 616 Session 2006-2007, 26 July 2007

Tinto, V. (1999). Taking retention seriously: Rethinking the first year of college. *NACADA Journal*, 19(2), 5-9